An award-winning technology developed at INL combines two known processes to create an efficient water-filtration system that can cleanse highly concentrated industrial wastewater to make purified water.

Scientist wins award for innovative water-filtering technology

By Alexandra Branscombe *for INL Communications & Governmental Affairs*

Hydraulic fracturing has been under fire for the amount of concentrated wastewater produced by the fracking process — up to 3 to 5 million gallons per drill site. However, a new technology developed at Idaho National Laboratory could change that by turning fracking wastewater back into potable water.

Switchable Polarity Solvent Forward Osmosis (SPS FO) is a groundbreaking technology, developed by a team led by INL researcher Aaron Wilson, which combines two known processes to create a brand-new, efficient water-filtration system. SPS FO can cleanse highly concentrated industrial wastewater to make purified water, and has won several outstanding innovation awards, including a 2013 R&D 100 Award, a Idaho Innovation Award for Early-Stage Innovation, and an Outstanding Technology Development Award from the Federal Laboratory Consortium Far West Region.

What is forward osmosis?

When someone opens a window on a warm spring day, usually a screen is in place – not just as a barrier to insects — but also to allow fresh air into the room. Forward osmosis acts in the same way: a permeable membrane allows water to pass through while keeping out particles or contaminants with specific properties.

The waste solution (black) is drawn through the filter system via forward osmosis where the clean water is drawn out (right side).

Osmosis works because water molecules "want" to move from an area of low solute concentration to high concentration to create equilibrium — just as water would be inclined to flow from a relatively dilute Kool-Aid mixture toward a heavily concentrated Kool-Aid. This is the challenge Wilson faced. For water to be drawn out of dirty, contaminated wastewater, the other side of the membrane would have to be even more concentrated.

At first, this may seem counterproductive: how do you purify water by pulling it into an even more concentrated solution? To answer that, Wilson looked to a new procedure, switchable polarity solvents.

Suddenly solvents

Wilson had only just started working at INL when he found a newly published field of research describing switchable polarity solvents (SPS). The literature, which said scientists used SPS to draw out oil from vegetables, jumped out to Wilson.

"I wrote 'Potential… for forward osmosis,'" said Wilson, pulling the original printout from atop his desk and pointing to the scribbled note he'd written more than three years ago. Wilson was inspired to combine SPS with FO as a water filtration system. "I couldn't sleep that night, I was so excited about the potential," he said. "I was also worried others had already done this."

No one had. Shortly after, Wilson earned funding through INL's Laboratory Directed Research and Development program and assembled a team of researchers. They later earned funding from an Innovation Development Fund. Fred Stewart, an INL expert in membrane research, helped Wilson find the right kind of membrane for the experiments: a delicate, highly porous membrane that allowed only water to pass through. The next challenge was building the experiment, which fell to Mark Stone.

SPS FO begins when the wastewater (or "feed" solution in lab lingo) is pumped past one side of a membrane. Simultaneously, the SPS solution is pumped past the other side of the membrane. The SPS solution is a combination of amines, water and a CO_2 trigger that creates a solution more

INL researcher Aaron Wilson demonstrates the SPS FO system.

concentrated than the wastewater. The SPS solution makes it possible for natural osmosis to pull water out of contaminated wastewater.

To separate the pure water from the SPS solution, the team simply applies heat. The heat causes a release of carbon dioxide, which turns the remaining SPS solution into an oily liquid that separates itself from the water, which is then siphoned off.

Applications to industry

The process is highly efficient. The CO_2 gas and now-oily SPS solution are fed back through the system, where the reintroduction of CO_2 triggers a polarity switch that changes the nonpolar oil back into a polar salt solution. The ability to switch between oil and a salt is what makes this a closed-loop system, ensuring a continuous flow of SPS solution. SPS FO is so effective at removing water from the contaminated solution that it can approach 100 percent water removal, said Wilson. That would be like pulling out all water from the Kool-Aid and leaving behind only crystallized sugar. This is not just step beyond current water filtration or desalination techniques. It is a running leap.

"SPS FO could be 20 percent the cost of [water filtration] that uses reverse osmosis because the heat energy that drives the process is 1/10th the cost of electricity," he said. Because the system needs only low-grade heat to separate water from the salts, SPS FO could be easily integrated into an energy system that emits heat, making the process even more environmentally friendly.

"I envision one or two trailers with the [SPS FO] filtration system parking next to a wastewater pond," said Wilson. He estimates that a trailer-mounted SPS FO system using spiral-wound filter modules could treat around 4,000 gallons per hour. At that rate, the system could filter the volume of an Olympic-sized swimming pool in a week.

"SPS FO can take fluid from the most concentrated waste stream you could possibly find, and make it into potable water," said Wilson.

He pointed out that depending on the requirements of the wastewater site, the SPS FO could produce pure water that could be safely released to the environment, or recycled back into the energy system — a benefit for closed-cycle fracking. The concentrated waste (after water is removed) can also have post-production uses, such as salt brines needed for fossil fuel production.

The next step for SPS FO

Wilson and his team have high hopes and an abundance of ideas for applying this new technology. For example, SPS FO could be applied in the biofuels industry as a process for extracting algae, explained Wilson.

The SPS FO technology is grabbing attention as a capability that could be applied in many arms of the energy industry — including nuclear, natural gas and petroleum. While Wilson and his research team have submitted a patent application for SPS FO, they are already fielding requests from companies both inside and outside the energy industry to apply this efficient and cost-effective technology. Winning the R&D 100 Award has helped validate the innovation behind the technology, gaining even more exposure.

The SPS FO development team includes, left to right, Mark Stone, Aaron Wilson and Fred Stewart.

"R&D 100 Awards are a tribute to the creativity and ingenuity of the INL research staff," said Todd Allen, INL's deputy laboratory director for Science and Technology. "In the case of this year's award, they show the value of translating laboratory investments into products useful to the nation."

Presented each year by R&D Magazine, the R&D 100 Awards recognize the top 100 technology products of the past year. Eligible technologies must be a new technical product (or process) available for purchasing or licensing and in marketable condition. Winners span industry, academia and government-sponsored research.

Like any passionate scientist, Wilson is much more excited talking about his research than about winning an award. Instead, he looks forward to seeing how the SPS FO can be used in the near future to help solve water issues around the world.

"I always like doing research that has an inherent value," said Wilson. "Water is one of those things where it is everyone's problem … and hopefully, this [technology] leads to good things."

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